Modeling the Impact of Minority Opinion Spreading

Tasheena Narraidoo

12/20/17

1 Abstract

The objective of my project is to model how minority opinion are spread in a network. In particular, my model aims to address three questions, namely, (1) how the network structure affects minority opinion spreading, (2) how committed minority agents affects this dynamics, and (3) how media supporting minority opinion can affect how minority opinion is spread across a network. We found that relatively more people are likely to change their opinion to that of the minority opinion in a network with relatively high degree connectedness. Committed agents supporting minority opinions are more likely to influence agents with different views and so a higher proportion of committed 'minority agents' in a network heavily affects how minority opinion is spread. Finally, the proportion of media supporting minority opinion contributes to changing agents' opinion to that of the minority opinion.

2 Background

The widespread use of online social network such as Facebook and Twitter has changed the dynamics of social interaction. Twitter has even recently changed its famous 140 character limit to a 280 one. Social networks have the ability to influence how people think, making information distributed on networks very powerful. During the past US presidential election, misleading information found its way on social networks and people started sharing and believing them. Many studies have been conducted pertaining to how public opinion is formed through social interaction. Stochastic models of the dynamics of how the mood of agents changes in a given network have also been created to analyze the impact of network density (Zhukov et al., 2017). Hegselmann & Krausse (2002) have investigated opinion dynamics using four different models (the classical model of consensus formation, a Friedkin and Johnsen variant model, a time-dependent structure, and a nonlinear model involving bounded confidence) and proceeded to analyzed the outcomes of each one. They went one step further by conducting computer simulations of nonlinear model involving bounded confidence so as to assess a spectrum of models.

However, not many studies have been made on assessing the structure of networks with external factors such as media influence. While sociophysical studies on how opinions are shaped abound (Axelrod, 1997; Hammond & Axelrod, 2006), modeling minority opinion in the sphere of politics and mass communication can be tricky because of the spiral of silence theory brought forward by Elisabeth Noelle-Neumann (1974). This theory suggest that people holding minority opinion tend to remain silent, fearing isolation (Noelle-Neumann, 1974). One study, however, found that given the right conditions such as network structure and mass-media influence, current minority opinion can become the majority opinion, despite the fact that people remain silent when holing minority opinions (Alvarez-Galvez, 2015).

In this project, we are modeling minority opinion spreading to analyze (1) how the network structure affects minority opinion spreading, (2) how committed minority agents affects this dynamics, and (3) how media supporting minority opinion can affect how minority opinion is spread across a network. We will look at the proportion of people believing in what is deemed as the majority opinion at the beginning of the simulation and the proportion of people believing in what is deemed as the minority opinion at the beginning of the simulation.

3 Method

We have followed the ODD (Overview Design Details) protocol designed by Grimm et al.(2006) to describe our model.

3.1 Purpose

The purpose of this model is to assess the impact of network connectivity, proportion of committed agents, and mass media on shaping/changing public opinion. In particular, we are interested in looking at how the proportions of agents holding minority and majority opinions change at the end of a one-year period. We will analyze the impact of degree connectivity (high connectivity vs. low connectivity) with no media influence and no committed agents. We will then analyze the impact of varying the proportion of committed agents in both low connectivity and high connectivity network. Finally we will analyze how varying the percentage of minority media affects a high connectivity network with committed agents.

3.2 State variables and scales

Table 1: Parameter Description

Parameters	Description	Scale/Metrics
NETWORK-TYPE	type of network	can be either spatial or preferential attachment
NUMBER-OF-NODES	average number of people	units
AVERAGE-NODE-DEGREE	average degree of network connectivity	units
COMMITTED-AGENTS-PERCENT	proportion of committed minority agents, i.e. agents trying to influence other agents	percent
MINORITY-EXTENT	average proportion of agents having minority opinion	percent
MINORITY-MEDIA-PERCENT	average proportion of media supporting minority opinion	percent

Table 2: Variable Description

Variables	Description	Scale/Metrics
MAJORITY	proportion of people supporting majority opinion	percent
MINORITY	proportion of people supporting minority opinion	percent
INDIFFERENT	proportion of people with no opinion	percent set at 5 percent at start
MINORITY MEDIA	proportion of media supporting minority opinion	percent
NUM-LINKS	number of links in the network	unit
AVERAGE DEGREE	actual average degree of network	unit
CLOCK	shows how many ticks have elapsed. An interaction occurs each day	1 tick = 1 interaction and 1 tick = 1 day

3.3 Process overview and scheduling

The models starts with the user choosing the `network-type` and the desired `number-of-nodes`. If the user chooses `pref-attach` for preferential attachment network, the `average-node-degree` is not used. However, if the user chooses `spatial` network, the user will have to specify the desired `average-node-degree`. Other variables the user has to set are `committed-agent-percent` which indicates approximately how many minority agents will be committed, i.e, they consciously try to influence the opinion of other agents, `minority-extent`, i.e approximately what percentage of people in the network supports the minority opinion, and `minority-media-percent`, i.e. the proportion of the mass media supporting and broadcasting the minority opinion. The nodes are then set randomly roughly according to these proportions to include a variability element. At each tick, a random agent (the speaker) will interact with one of his neighbors (the listener) chosen at random. Then given the degree of connectivity of the network, the nature of both the listener and the speaker (committed or not, media or not, minority or majority or indifferent), the listener has a probability of changing his/her opinion to that of the speaker. We assess the interactions over a year (i.e. 365 ticks). The model was adapted from adapted from the 'Social Conception of content' model by Noam Drory (2017) which models how individuals on a network influence one another when it comes to content delivery such as offensive content.

3.4 Design concepts

Emergence: Opinion dynamics arise from the interaction of the agents but an agent's influence level depends on whether the agent is committed or not and and influence of the other agent he is interacting with.

Sensing: Each agent knows their neighbors, their type (media or not), their opinion, whether they are committed or not, whether they are the speaker or the listener in an interaction, the opinion of their neighbors, the type of their neighbors, whether their neighbors are committed or not. They also know the probabilities of influencing their neighbors or of being influenced during an interaction.

Adaptation: Committed agents that support minority opinion and minority media have a better chance of influencing an uncommitted agent holding the majority opinion and will definitely influence an indifferent listener.

Interaction: At each interaction, there is a probability that the speaker agent affects the listener agent given the characteristics of each agent (committed?, minority-media?, opinion?).

Stochasticity: All agents are given their attributes (committed?, minority-media?, opinion?) randomly based on the variable's proportions. A listener changes his/her opinion based on a probability given his/her attributes and those of the speaker.

Observation: For model testing, the spatial distribution of the agents and the proportion of opinions were observed process by process. For model analysis, we measure proportion of each opinion at the end of each year.

Collectives: Since we are modelling networks and interactions, the agents are modeled in networks and people are affected by their immediate neighbors while media do not change their views.

3.5 Initialization

The models starts with the user choosing the `network-type` and the desired `number-of-nodes`. If the user chooses `pref-attach` for preferential attachment network, the `average-node-degree` is not used. However, if the user chooses `spatial` network, the user will have to specify the desired `average-node-degree`. Other variables the user has to set are `committed-agent-percent` which indicates approximately how many minority agents will be committed, i.e, they consciously try to influence the opinion of other agents, `minority-extent`, i.e approximately what percentage of people in the network supports the minority opinion, and `minority-media-percent`, i.e. the proportion of the mass media supporting and broadcasting the minority opinion. The types of nodes are then set randomly in a network according to the network type and roughly according to the variable proportions assigned to include a variability element. The agents with majority opinion are in red, those with minority opinion, green, and the indifferent agents are white. Committed non-media agents are represented by squares, minority-media by a triangle colored with a light shade of green while the rest of the agents are circular nodes. On creating a network the nodes are randomly linked. The number of links and the average degree of the nodes are displayed. The majority, minority, indifferent, and minority-media are assigned a proportion.

3.6 Input

For the inputs, as stated above, the user chooses the `network-type` and the desired `number-of-nodes`. If the user chooses `pref-attach` for preferential attachment network, the `average-node-degree` is not used. However, if the user chooses `spatial` network, the user will have to specify the desired `average-node-degree`. Other variables the user has to set are `committed-agent-percent` which indicates approximately how many minority agents will be committed, `minority-extent`, and `minority-media-percent`. The nodes are then set randomly according to the network type and roughly according to the variable proportions assigned to include a variability element.

3.7 Submodels

opinion assignment rules: When each agent representing a person is created, if a random number A is less than the proportion of committed agents, and if a random number B is less than the proportion of minority agents, the opinion is assigned to be that of a minority and the agent is a committed one. If B is greater, then the opinion is assigned to be that of the majority. If A is greater than the proportion of committed agents, and if a random number B is less than the proportion of minority agents, the opinion is assigned to be that of a minority and the agent is not a committed one. If B is greater, then the opinion is assigned to be that of the majority. All agents with the majority opinion are uncommitted. This is because we assume that people having a majority opinion do not need to convince other people. After each node is assigned to be either `minority` or `majority`, 5% of them nodes are chosen at random and are labeled as being `indifferent` and not committed. Agents with indifferent opinions belong neither to the majority nor to the minority unless they are influenced by committed agents or the minority media.

minority media rules: The number of nodes assigned to the media is the lesser of 6 and `number-of-nodes`/5, to take into consideration networks with less than 30 nodes. Then the number of nodes allocated to the minority media are assigned in relation to the `minority-media-percent`. Minority media are all committed agents. They are represented by light green triangles on the network. They are not influenced by other agents. Only the effects of minority media agents are considered in the network and so majority media are not included in the network.

interaction rules: At each tick, a node is randomly chosen to be the speaker and one of its neighbors is randomly chosen to be the listener. We don't consider cases where the listener is a media node as their opinions cannot be changed. We also ignore interactions where both agents share the same opinion. We have also considered whether the network has nigh connectivity or not. The probability that a listener changes his/her opinion to that of the speaker's can be summarized in the following tables. Omitted cases are assumed to have a conversion probability of zero. Whether or not the network is highly connected, the following probabilities for indifferent listener in Table 3 apply.

Table 3: Conditional Probabilities for indifferent listener

case	Speaker media?, committed?, opinion?	Listener opinion?	Probability
1	media, committed, minority	indifferent	1
2	not media, committed, minority	indifferent	1

Table 4: Conditional Probabilities for low connectivity

case	Speaker media?, committed?, opinion?	Listener committed?, opinion?	Probability
1	not media, committed, majority	committed, minority	0.3
2	not media, uncommitted, majority	committed, minority	0
3	not media, committed, majority	uncommitted, minority	0.4
4	media, committed, minority	committed, majority	0.5
5	media, committed, minority	uncommitted, majority	0.8
6	not media, committed, minority	committed, majority	0.3
7	not media, uncommitted, minority	committed, majority	0
8	not media, committed, minority	uncommitted, majority	0.7

Table 5: Conditional Probabilities for high connectivity

case	Speaker media?, committed?, opinion?	Listener committed?, opinion?	Probability
1	not media, committed, majority	committed, minority	0.5
2	not media, uncommitted, majority	committed, minority	0.9
3	not media, committed, majority	uncommitted, minority	0.3
4	media, committed, minority	committed, majority	0.85
5	media, committed, minority	uncommitted, majority	0.97
6	not media, committed, minority	committed, majority	0.7
7	not media, uncommitted, minority	committed, majority	0.5
8	not media, committed, minority	uncommitted, majority	1

4 Results

The two outcome measures are the proportion of agents backing what at the beginning was the majority opinion (Majority) and the proportion of agents backing what at the beginning was the minority opinion (Minority). We want to see if the majority opinion could become the minority opinion and if the minority opinion could become the majority opinion after one year (365 ticks). For our analysis, we will concentrate on one type of network `spatial` networks and the we always started with a minority opinion of approximately 30% in all instances. High network connectivity means that the average degree of a network is greater than 5 while low network connectivity means that the average degree of a network is less than 4.

4.1 Overview of the model

The three figures below illustrate how our model works. The circular nodes represent uncommitted agents, the square are committed people and triangles represent the minority media. Agents supporting the majority opinion are in red, those supporting the minority opinion are in green, and indifferent agents are colored white. In Figure 1, the parameter values are set and tick is at 0. In figure 2, the model was stopped at 369 ticks and we see from the graph that the minority opinion is becoming more popular. By the 687th tick, the minority opinion has overcome the majority opinion. However, for our analysis we have set a limit of 365 ticks which represents a year.

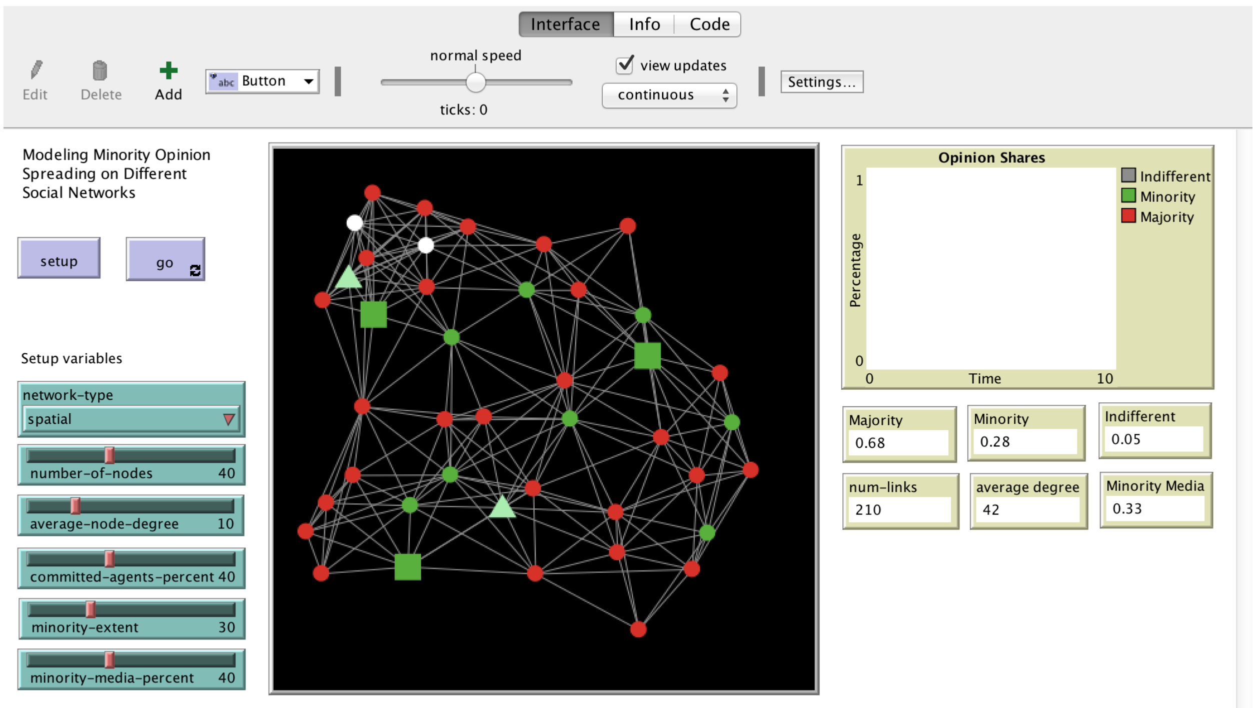

Figure 1

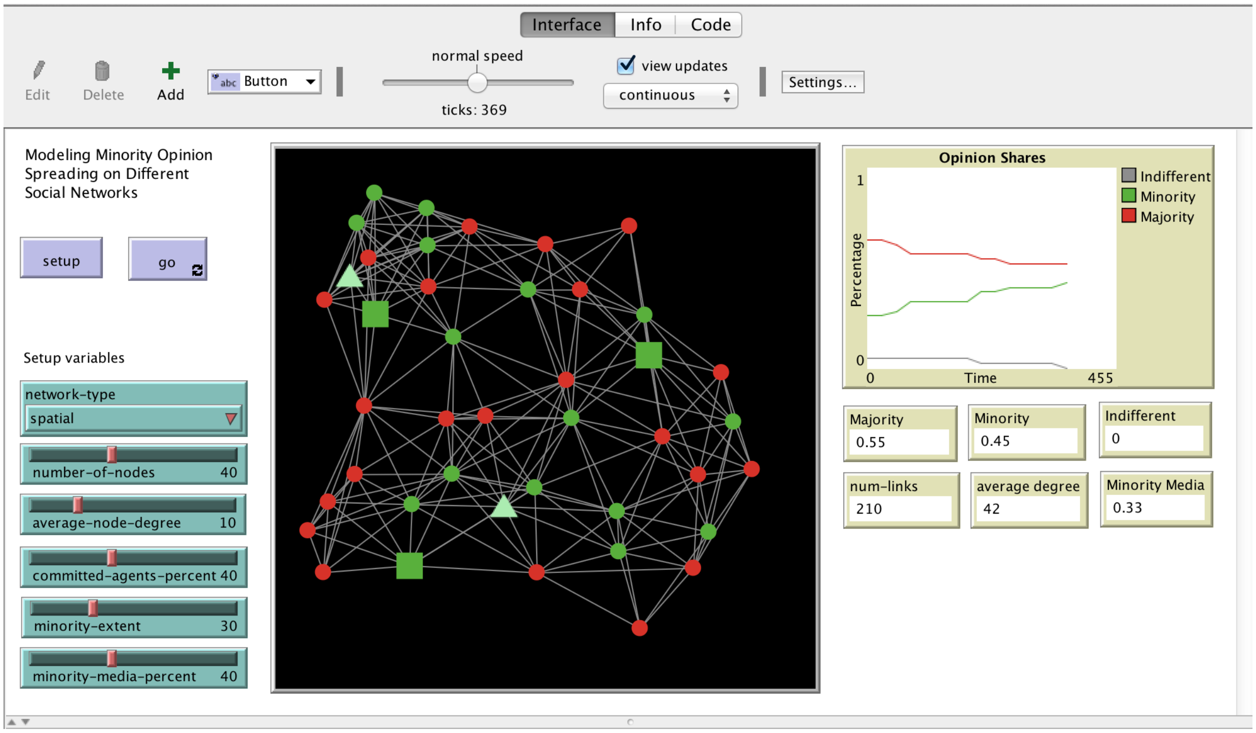

Figure 2

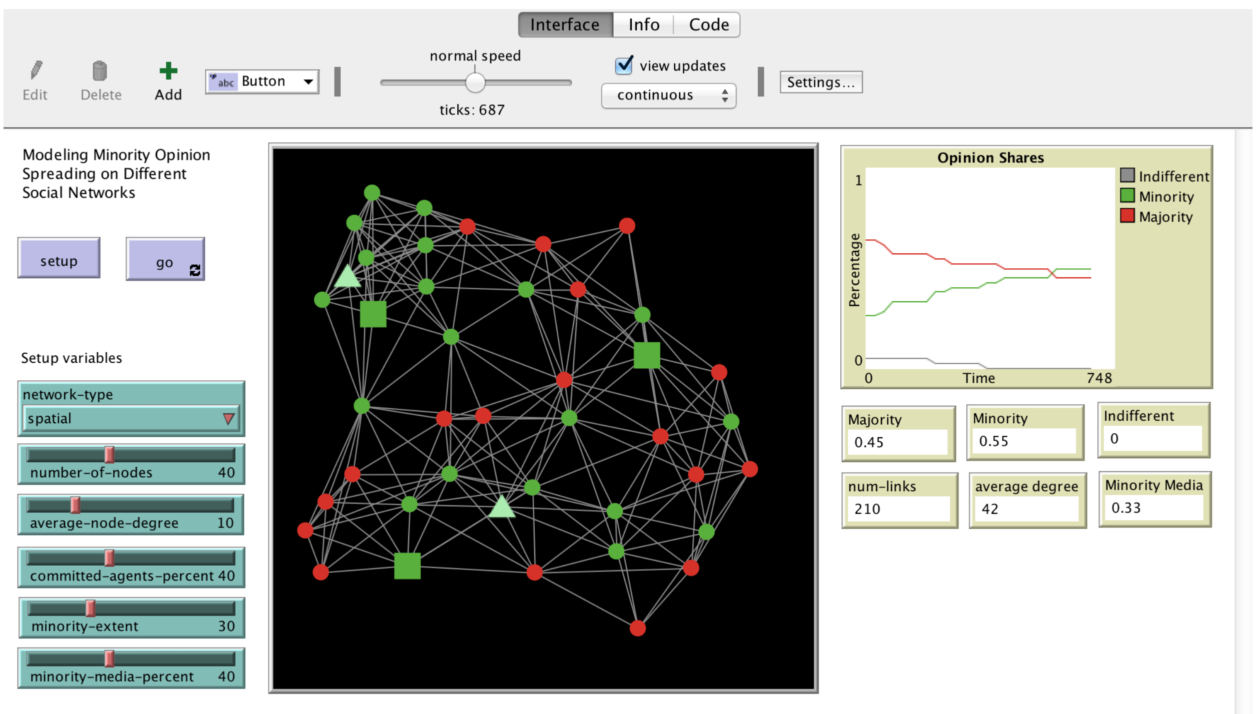

Figure 3

4.2 Effects of Network Connectivity

We first analyzed how the original majority and minority opinions are spread after one year. There are no committed agents and media influence in this scenario. 20 simulations were run by varying 10 values for `average-node-degree` and 1040 observations were obtained for each opinion. We then reported the actual average degree.

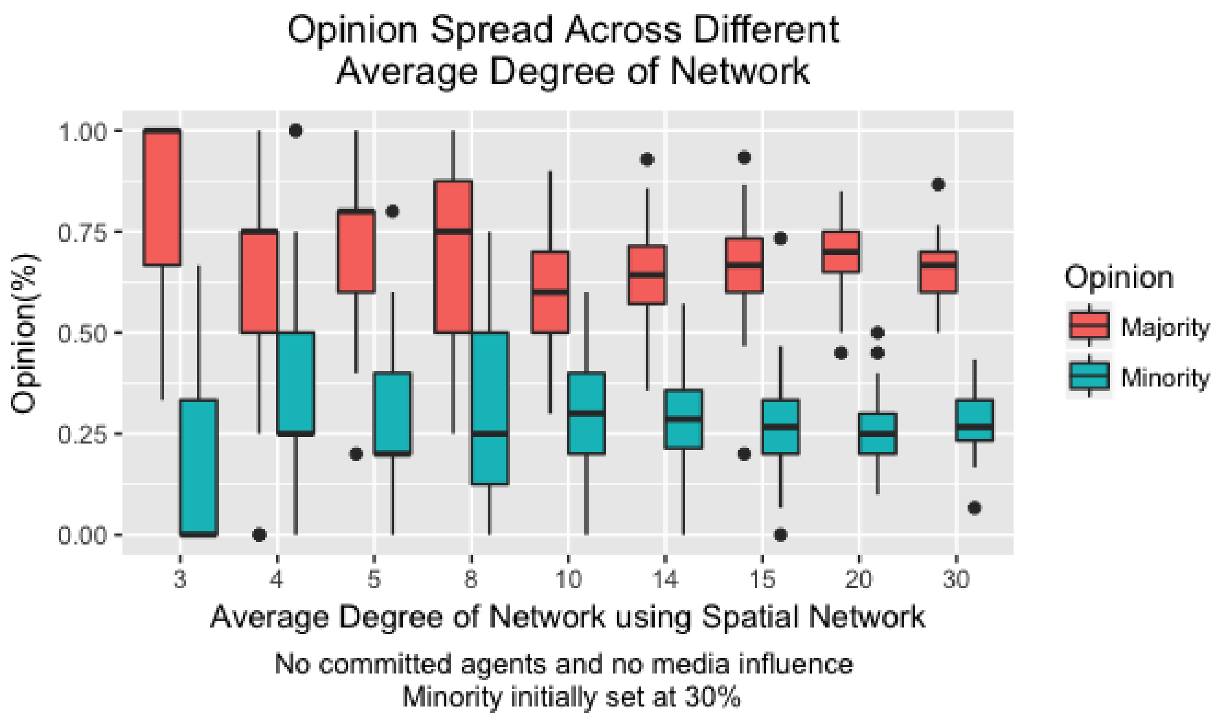

Figure 4

From the figure above we see that as the average node degree increases the median of the majority opinion falls. For networks with low connectivity, medians of majority opinion is quite high. We notice that in many instances, for low networks, people with minority opinion go with the flow and accept the majority one. This can be due to the fact that people fear isolation and this fear would be even greater in smaller networks. However, in some instances the minority opinion takes over the majority one for nearly all average degree levels. There is also less variability in more connected networks, suggesting, without agents actively trying to influence one another, agents tend to keep their own opinion.

4.3 Effects of Committed Agents

Next we look at the effects of committed agents on the network. We consider the cases for both a high connected and low connected network. There were no media influence for this scenario. We considered proportion of committed agents at 10%, 30% and 50%. We considered spatial networks with average degree of 3, 4, 5, 8, 10, 14, 15, 20, and 30. Twenty simulations were run an 3120 observations for each opinion were obtained. Here again, high degree networks are networks with average degree above five.

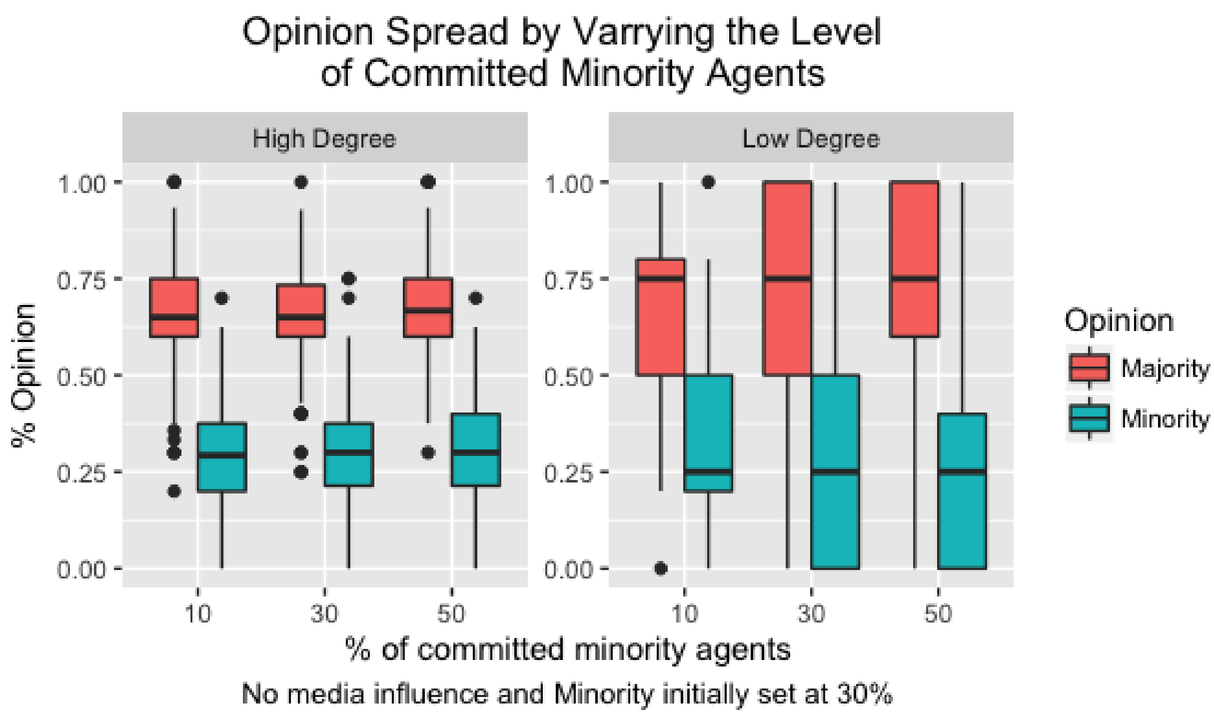

Figure 5

From the above figure we can see that, in the case of minority opinions, high degree networks have a relatively higher median as compared to low degree networks and there is also less variability. In many cases, for both high and low degree networks, we see that minority opinions have crossed the 50% public opinion threshold, and so they have become the new majority opinion. However, the median is still at the average 30%. For majority opinions, we see that in low degree networks, people with minority opinions are more likely to switch to the majority opinion and this can be gain attributed to the fear of isolation which is more pronounced in smaller social circles. The high level of variability as compared to high degree networks might stem from scenarios where committed agents are able to influence their neighbors. Since these are small circles, it is easier to influence the whole cluster.

4.4 Effects of Media Influence

We now add the effects of media influence in our model analysis. We consider high degree spatial networks (i.e. networks with average degree greater than 4) since from Figure 4 we see that minority median was higher as compared to networks with low degree of connectivity. We set the level of committed minority agents at 40% since there did not seem to be a significant difference as we increase level of committed agents from Figure 5. The initial level of minority opinion is approximately 30%. We ran 20 simulations and obtained 1440 observations for each opinion. We considered the extreme case where minority-media is at 50% and we also plotted the absence of minority media to analyze the trend.

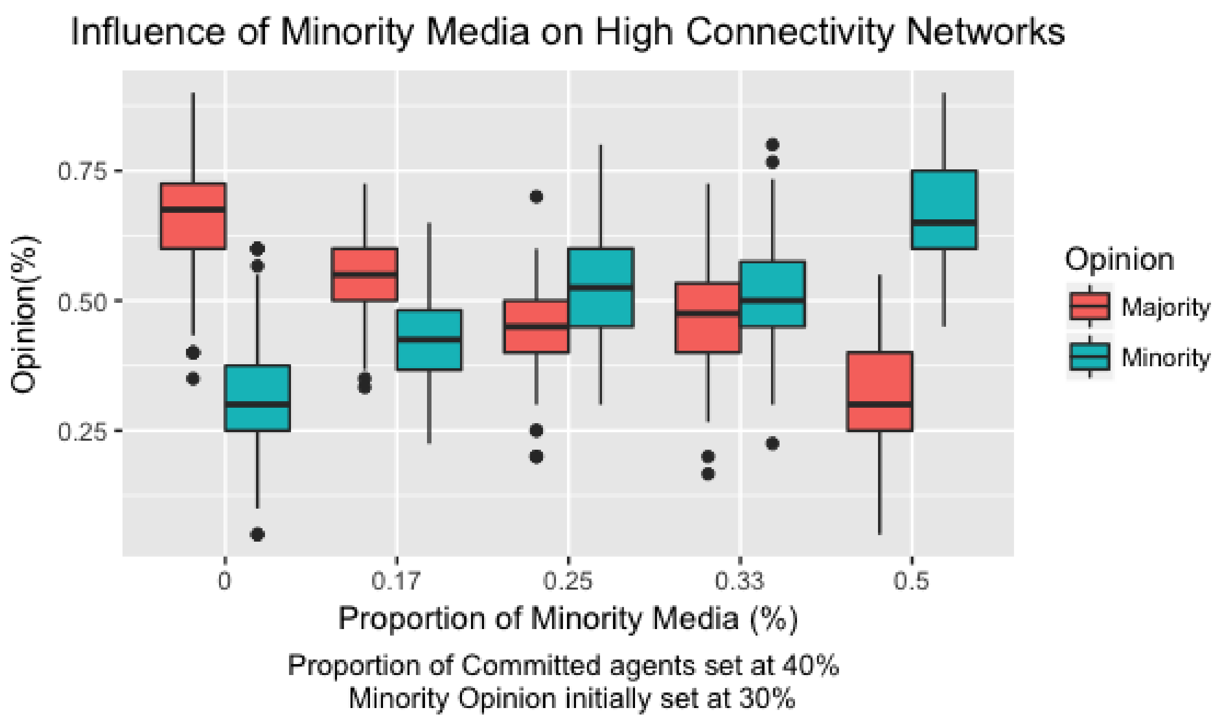

Figure 6

From the above plot we see that, in the absence of media influence, minority option has the lowest median and majority opinion has the highest median. However, as we increased the presence of minority media in the network we see that the minority opinion gains popularity and overtakes what originally was the majority opinion. We see that in highly connected networks with the presence of committed people, adding media influence in the equation, there is a higher chance of minority opinion winning against majority opinion over the course of a year.

5 Discussion

We have analyzed the effects of degree of connectivity of networks on majority and minority opinions. For networks with low degree of connectivity, medians of majority opinion is relatively higher than for networks with high degree of connectivity. This would suggest that minority opinion has a relatively higher chance of gaining popularity in networks with high degree of connectivity. Next we considered the effects of adding committed people to our model and we saw that low degree models had more variability. However, there did not seem to be a significant difference as we increased level of committed agents. So, to analyze the effects of media influence on minority opinion spreading, we selected high degree networks with a fixed level of committed agents. As we increased media influence, we saw that minority opinion became the new majority opinion and vice versa.

The parameters and outcomes are in line with the results of Alvarez-Galvez (2015) who found that minority opinions (10%) have a greater chance of winning over the majority opinion (90%) if there is a certain minimum level of committed agents (10%), high degree of connectivity between neighbors and/or adequate support from mass media (10-30% media sources supporting minority opinion). The probabilities differ depending on the degree of network connectivity and Zhukov et al. (2017) found that stochastic dynamics change when social networks expand. Our results for lower median in low connected networks seems to confirm the spiral of silence theory by Elisabeth Noelle-Neumann (1974). We have over 1000 observations to work with in each case, which gave us an overall view of the model and reduced errors that might arise due to variability. The model also allows us to see the change in opinion as it occurred and we were able to see how clusters of opinions are formed. We only used spatial networks for our analysis. Future work might include analyzing other network structures such as preferential attachment networks. We could also have different levels of committed agents within a network, each with a different probability of influencing another agent. In our model, we held media opinion constant. It would be interesting to include the possibility of media being influenced by other agents. Our model was limited in terms of the size of the networks. A larger network would have allowed us to add majority media.

6 Conclusion

As we have seen from the model, given a high connected network, with committed agents and media influence, minority opinions have a higher chance of becoming the new majority opinion. This is not what we would normally expect as people with minority opinion tend to remain silent, fearing retribution. This is probably where media influence is crucial. With more media supporting minority opinion, people might feel this is not a 'minority' opinion anymore and will try to convince other people. Social networks such as Facebook are a form media, where news are circulated and people can share these news and influence people in their friend list.

7 Reference

1. Alvarez-Galvez, J. (2015). Network models of minority opinion spreading: using agent-based modeling to study possible scenarios of social contagion. DOI: 10.1177/0894439315605607 Retrieved from http://journals.sagepub.com/doi/abs/10.1177/0894439315605607

2. Noam Drory (2017). Social Conception of content Netlogo model. Retrieved from http://ccl.northwestern.edu/netlogo/models/community/Model%202%20-%20Social%20Conception%20of%20content

3. David Hales. Virus on a network model with addition of network topologies pref-attach for module: http://davidhales.name/abm-netlogo/ Retrieved from http://davidhales.name/abm-netlogo/lab-networks/

4. Grimm et al. (2006). A standard protocol for describing individual-based and agent-based models. Retrieved from http://www.bio.uib.no/modelling/papers/Grimm_2006_A_standard_protocol.pdf

5. Noelle-Neumann, E. (1974). The spiral of silence: A theory of public opinion. Journal of Communication, 24, 43–51. DOI: 10.1111/j.1460-2466.1974.tb00367.x Retrieved from http://onlinelibrary.wiley.com/doi/10.1111/j.1460-2466.1974.tb00367.x/abstract

6. Hegselmann, R., & Krausse, U. (2002). Opinion dynamics and bounded confidence: Models, analysis and simulation. Journal of Artificial Societies and Social Simulation, 5, 3. Retrieved from http://jasss.soc.surrey.ac.uk/5/3/2/2.pdf

7. Zhukov et al. (2017).Stochastic Dynamics of Influence Expansion in Social Networks and Managing Users' Transitions from One State to Another. Retrieved from https://www.researchgate.net/publication/319553342_Stochastic_Dynamics_of_Influence_Expansion_in_Social_Networks_and_Managing_Users%27_Transitions_from_One_State_to_Another

8. Axelrod, R. (1997). The dissemination of culture—A model with local convergence and global polarization. Journal of Conflict Resolution, 41, 203–226.

9. Hammond, R. A., & Axelrod, R. (2006). The evolution of ethnocentrism. Journal of Conflict Resolution, 50, 926–936. Retrieved from http://journals.sagepub.com/doi/abs/10.1177/0022002797041002001